APPENDIX H
PRELIMINARY STATEMENT OF PROPOSED NEAR COASTAL MARINE NUTRIENT SAMPLING AND REFERENCE CONDITION DEVELOPMENT PROCEDURE

Synopsis of the National Nutrient Criteria Program, Coastal Marine Sampling Design Planning Meeting, 4-5 June 2001, USEPA Environmental Science Center, Ft. Meade, MD.

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Background and Purpose

Cultural eutrophication is an established water quality management concept and concern reaching as far back as the 1600s in America (Capper, Power and Shivers 1983). However, extensive public recognition of this form of pollution in coastal waters is relatively recent. The publication "Eutrophication, Causes, Consequences, and Correctives" (NAS 1970) is often perceived as the technological beginning of American nutrient pollution awareness and is centered on the understanding and abatement of this problem primarily in freshwater lakes and reservoirs. We have since come to better understand the problem in streams, rivers and estuaries with the publicity and public involvement in the Chesapeake Bay studies of the 1980s. Vollenweider, Marchetti, and Viviani published "Marine Coastal Eutrophication" in March of 1992 and this volume may be considered the coastal equivalent of the land mark NAS freshwater publication a decade earlier.

In response to this growing awareness, the EPA National Nutrient Criteria Program is preparing technical guidance for nutrient reference condition determination and related criteria development to be used by States and Tribes in the reduction of cultural eutrophication of the Nations' surface waters. This report concentrates on coastal marine waters and the effort to identify relatively natural nutrient water quality conditions, which can be used as a benchmark to evaluate cultural eutrophication or overenrichment. A preliminary literature investigation and data search indicate that insufficient data exist to derive the reference condition information suitable for the needs of the Program without going to primary data collection.

Because data gathering is likely to be a preliminary concern as well as an ongoing requirement, this meeting of coastal marine nutrient research and management specialists was called to design a standard protocol that the EPA can recommend for use in U.S. marine coastal waters. Coastal marine waters are defined as those waters within 20 miles of shore along the East, West, and Gulf coasts of the United States as well as Alaska, Hawaii, and the U.S. Trust Territories. Emphasis is on the three mile limit State waters, although interest may devolve to the 12- mile U.S. limit as well. Nutrient loading from cultural land run off sources are not presently expected to be a serious problem beyond this limit. The general design and protocol are applied here to a case study example, the coastal waters of the mid-Atlantic Bight from New Jersey to the Virginia Capes. Many of the design elements, in particular the number, size and placement of spatial elements (strata and cells; see below) would need to be modified for specific applications in different parts of the U.S. coastline.

A coastal transect of fixed stations exists for most of the Mid-Atlantic Bight, which has been used by EPA and NOAA for several years to collect nitrogen, phosphorus, Secchi depth (SD), and chlorophyll-*a* (Chl-*a*) data. This procedure and data base will be the prototype presented and discussed to develop the recommended protocol.

Objective
To determine a simple, cost effective, scientifically defensible and standardized method to sample for marine enrichment variables to use in determining reference condition for nutrient criteria derivation.

Premise of the National Coastal Nutrient Criteria Program
Offshore marine and onshore, near-coastal sites removed from point and estuarine discharges can be identified as reference sites reflecting the least culturally impacted nutrient water quality of a region. "Region" in this case is a geographically similar portion of the coastline such as the Mid-Atlantic Bight. Such regions can also be described from the coastal portion of the Level III nutrient ecoregion map of the continental United States (which is consistent with the rest of the National Program and is similar to the ORD Provinces used by EMAP).

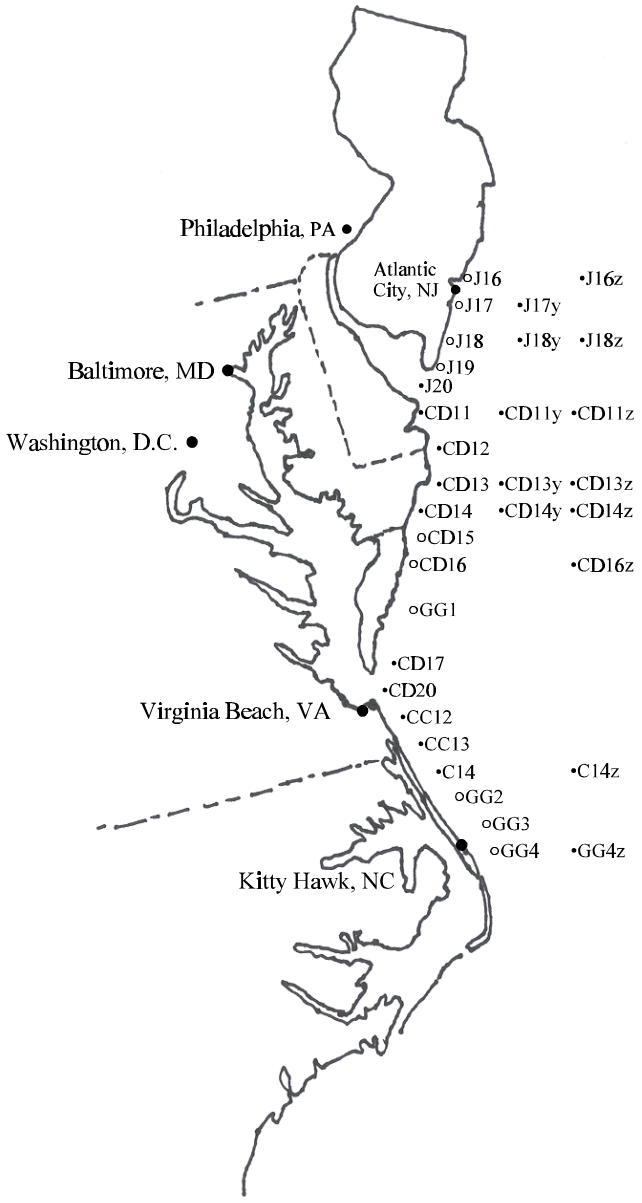
Nutrient water quality is established from representative sampling of the coastal waters at these a priori reference sites. The other elements of nutrient criteria, i.e., historical trends, modeling of the data for additional insights, and attention to the consequences down-current of any proposed nutrient criteria, and assessment of all of this information by a Regional Technical Assistance Group (RTAG) are applied to the initial reference condition values to develop nutrient criteria for total phosphorus (TP), total nitrogen (TN), Chl-*a*, and SD.

These criteria can then be used by States and Tribes to manage and monitor the nutrient quality of their coastal marine waters. While this concept was developed and initiated by the USEPA beginning with the Biological Criteria Program in 1989 (EPA-440/5-90-004, EPA-440/5-91-005) and further refined and applied to nutrients by the EPA National Nutrient Criteria Program in 1995 (EPA 822-R-96-004, EPA 822-R-98-002), the idea has also been independently developed by the Swedish Environmental Protection Agency using the reference condition approach on a regional basis and employing the same indicator variables (Report number 5052, 2000).

Importance
All other waters of the continent drain to the coast and these coastal marine areas are the recipient of any nutrients not intercepted from that cumulative runoff. Globally, conditions of many coastal areas have shown several-fold increased levels of nitrogen and phosphorus since industrialization (Smith 1998, Smith, Tilman and Nekola 1999), and preliminary assessments of empirical data collected from the Mid-Atlantic Bight between New Jersey and North Carolina by USEPA Region III since 1987 have suggested an upward trend in the concentration of both dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) at stations approximately 1 to 5 nm off shore (Muir, pers com, 2001). An extensive baseline of region specific coastal nutrient data, regularly and consistently collected, is needed to establish criteria against which future loading conditions may be compared. Potential predictive models may also be developed from this information relating algal booms and other biological responses to these nutrient levels in coastal waters.

The Transect Sampling Design
As illustrated below (Figure H-1, of coastal sampling stations between Atlantic City, NJ and Kitty Hawk, NC) a series of transect sampling stations have been located between one and five miles from shore along a designated coast line to measure ambient water quality as reflected in TN, TP, Chl-*a* and SD. Data collected from those stations determined to be remote from significant cultural impacts such as sewage

Figure H-1. Example of an initial coastal monitoring project conducted off the mid-Atlantic shelf just north of Delaware Bay and south of the mouth of the Chesapeake Bay to obtain nutrient reference condition values. Open circles are reference sites and the inshore references are compared to the offshore ones for confirmation.



discharges, industrial activities, major port facilities, or estuarine discharges constitute the reference condition. The values measured can be compared to marine conditions further offshore (e.g., 20-25 nm) reflecting, at least for TN and TP, the unimpacted condition.

This comparison, together with attention to prevailing currents including upwellings, would establish the seasonal values for TN, TP, Chl-*a*, and SD. Salinity would also be an important variable to document local constancy of the waters and to avoid discharge plumes from rivers and estuaries that are not part of the defined coastal waters of concern. These estuarine and riverine waters should have their own criteria.

Data have been collected from the surface 1 meter, mid depth, and the bottom 1 meter of the water column at each station. Measurements are made on a seasonal basis, essentially mid-summer and mid-winter and with sufficient data, criteria can be established for each season. While the protocol as described above has been in use for about twenty years, most of those data are for dissolved inorganic nitrogen and phosphorus rather than TN and TP, Chl-*a*, and SD. The TN, TP and off shore stations are a recent addition and only two summers of data are available which is reported here.

Data Collection

Operations are during daylight hours only in order to include SD measurements with surface nutrient collections and to maintain a consistent nutrient depth profile relative to photo periodicity. Additional data collected with a CTD includes salinity, pH, temperature, depth, conductivity, and DO.

Data sampling points presently include the discharge plumes of estuaries, rivers, and point dischargers to monitor impacts and design management plans, but not as part of the proposed coastal reference condition sampling system per se.

The Pilot Project

The area approximately between Atlantic City, NJ and Kitty Hawk, NC has been studied by EPA Region III for about 17 years and includes a mix of nutrient, chemical, biological, and physical measurements. This data has been processed and will provide trend information about the area.

For the last two summers and one winter, nutrient data have been collected from this area in the manner described above. This is the initial basis for a reference condition determination and is presented in Figures H-2 a-d, below.

If the pilot project is judged successful, it is expected that the process, training, and funds for similar equipment will be provided to each of the coastal EPA Regions for comparable operations to develop their ecoregional coastal nutrient criteria. This area more than any other because of the proximity of State and Federal waters will lend itself to joint data gathering and criteria development.

Methods and Materials

Forty-nine sampling stations are located along the 200 nautical mile (nm) stretch of coastal waters. There are twenty stations roughly 10 miles apart situated one to five miles off shore (total of 39 consisting of either single stations or sets of two or three), there are five intermediate (ten miles off shore) stations, and there are eight stations located about 20 nm offshore (Figure H-1).

Sampling was conducted from the OSV Peter W. Anderson using a Sea-Bird brand CTD and rosette sampler with 30 L Niskin bottles to produce a continuous water column profile and discrete water samples from the surface one meter, the mid-depth, and the bottom one meter of the water column at each station. One liter of sample was filtered using a Millipore Corporation apparatus and 0.7 um fiberglass filters (Whatman GF/F). Ten ml sub-samples each of water were taken for TN and TP analysis using the

Figure H-2a. Two-year summer nutrient survey results using a sampling design as illustrated in Figure 1. Potential reference condition for summer conditions is 0.025 mg/L TP (NM = nautical miles).

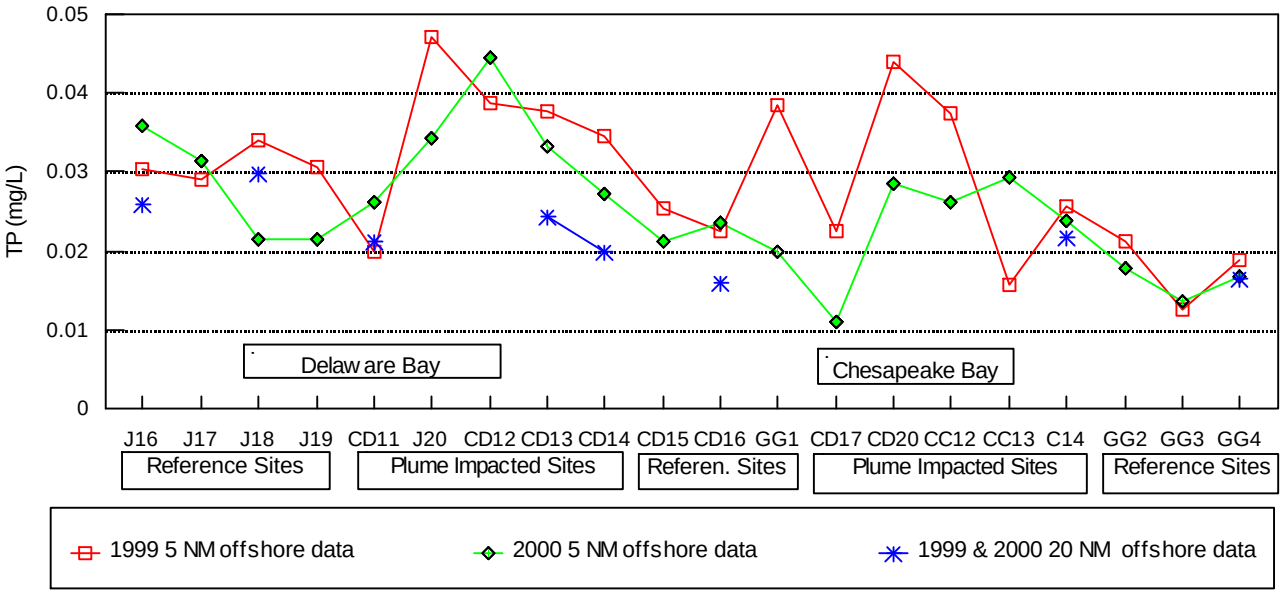


Figure H-2b. Two-year summer nutrient survey results using a sampling design as illustrated in Figure 1. Potential reference condition for summer conditions is 0.175 mg/L TN (NM = nautical miles).

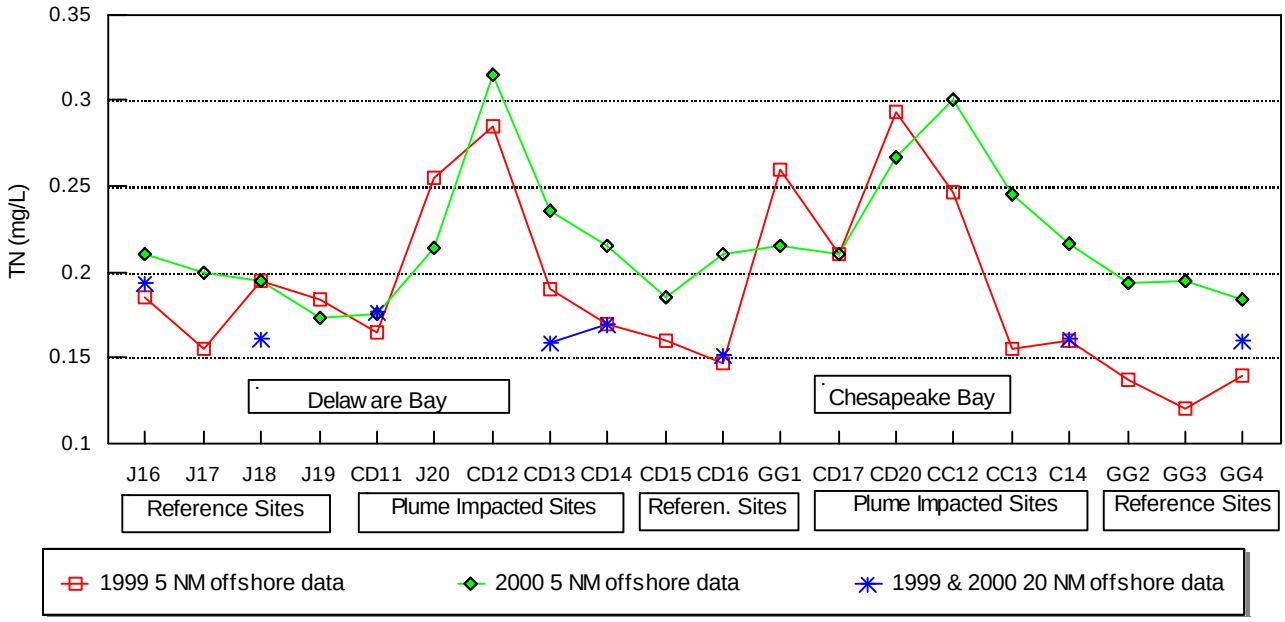


Figure H-2c. Two-year summer nutrient survey results using a sampling design as illustrated in Figure 1. Potential reference condition for summer conditions is 0.09 µg/L chlorophyll-a (NM = nautical miles).

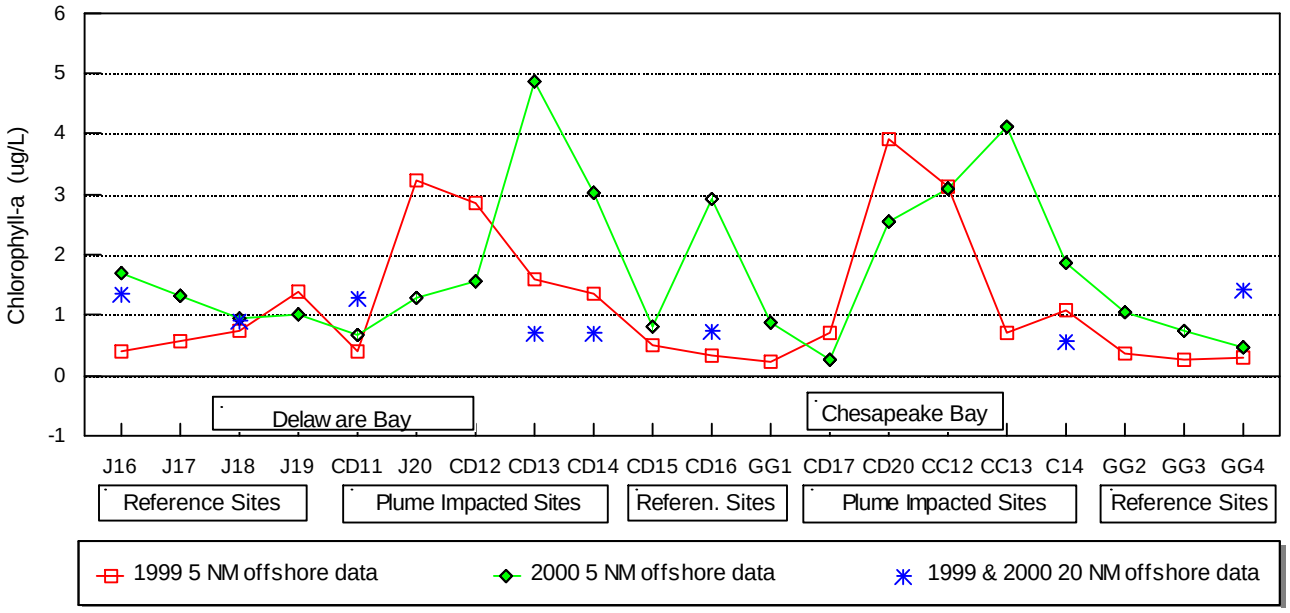
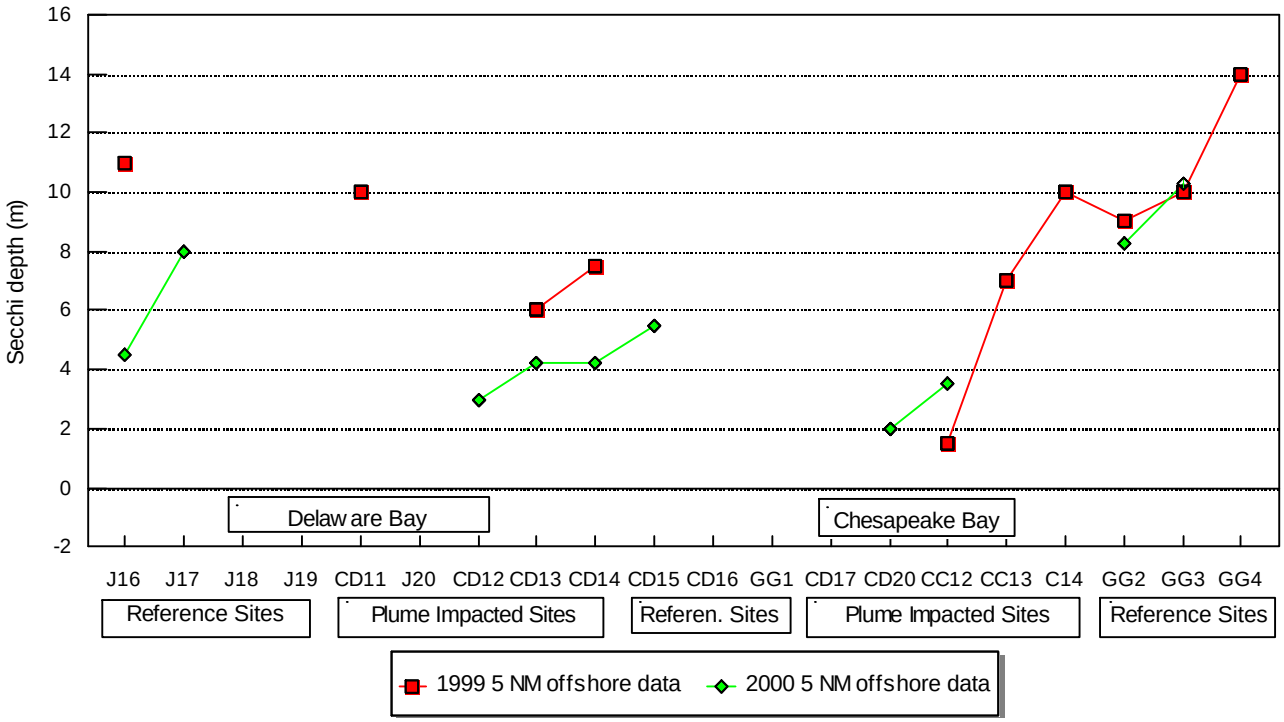


Figure H-2d. Two-year summer nutrient survey results using a sampling design as illustrated in Figure 1. Secchi depth data are incomplete because of missing observations during night-time operations (NM = nautical miles).



Standard Methods persulfate digestion method. All samples were frozen on board for later analysis at the University of Maryland Chesapeake Biological Laboratory. Secchi depth was determined using a 35 cm diameter white Secchi disc on 0.5 m marked line.

Results

Preliminary data analyses indicated that the groupings of two or three stations (originally intended to reflect progressive off shore encroachment of nutrient runoff) are not significantly different. Similarly, initial assessment of the surface, mid-depth, and bottom water column samples showed no significant differences for the nutrient criteria indicators except for DO. Salinity did show the expected surface to bottom variations expected of near coastal waters. Consequently horizontal and vertical sampling distances for each station were combined to produce the nutrient results presented here.

The following figures illustrate the results of two summer surveys in 1999 and 2000. Data indicated by an asterisk represents the mean of combined two year data from each 20 nm off shore station. Gaps in the Secchi depth results are because of the night time intervals during 24-hour operations. The stations located in the vicinity of the estuarine discharges of Delaware and Chesapeake Bays are indicated by the appropriately labeled open boxes, i.e. J18 through CD12 for the Delaware and CD17 through CC13 for the Chesapeake.

Discussion

- The survey technique appears to faithfully reflect the nutrient conditions of the coastline in that higher nutrients were found in the waters just off each estuary. Further, when surface station salinity was plotted, a mirror image of the nutrient data results was presented indicating a freshwater correlation with higher nutrient concentrations. The biological response of the waters was also evident from the correlation of Chl-*a* and SD data with the TN and TP levels.

- Given the variability in only two years of data, it is interesting that the offshore stations appear to be relatively consistent in all three nutrient parameters. The incongruity of the TP and TN data at GG1 for 1999 and for chlorophyll-*a* at CD16 for 2000 is also noted, but unexplained.

- The two consecutive sampling years demonstrated similar trends among the stations indicating no major weather variability during this period and also suggesting that the proposed reference sites respond comparably to the discharge sites to inter-annual climatological events.

- The stations that consist of sets of two or three sites within a few miles of one another were determined upon review of the data to have very little distinction. This suggests that perturbation, if any, originating from the coastal land mass has had an impact over all three sites.

- It appears that the Delaware plume drifts more southward from the mouth of its bay than does the Chesapeake. This may reflect the lower discharge volume of the Delaware and the influence of the Hudson River discharge and Longshore current, both displacing the plume southward. Similarly, the slight northward offset of both the Delaware and Chesapeake plumes in 1999 relative to 2000 may be a response to changing coastal current dynamics from year to year.

- There was no significant difference between the eight offshore sites (20 nm offshore) and their inshore counterparts. Further comparison of offshore stations to those counterparts within the estuarine discharge plumes will help determine the sensitivity of the comparison. The intermediate 10 nm stations do not appear to add substantial information and can be discontinued except in the vicinity of discharge plumes to help define these margins.

While the data is limited, it is encouraging that the offshore controls are comparable to the expected inshore reference sites. Candidate inshore reference sites are initially selected on the basis of an apparent physical absence of local cultural impact, i.e. tributary discharges, municipal discharges, ports or marinas, or other commercial enterprises. Because of the potentially high variability in the existing data, a concurrence between offshore and inshore reference stations is not necessarily confirmation of the quality of the inshore reference sites, but when consistent with observed physical indications, this information adds confidence to the selection. Conversely, significant differences would be cause for suspecting the inshore site selection as of reference quality.

- In this regard, an interesting trend was noted among the three groups of reference sites located north of Delaware Bay; between Delaware and Chesapeake Bay; and south of Chesapeake Bay (Figures 2a-d). The mean ambient concentrations of TP, TN and Chlorophyll-*a* at these reference sites trend downward from north to south. The same trend appears in the eight stations 20 nm offshore presumably reflecting a broad scale process affecting this area. This further supports the importance of establishing relatively close spaced reference sites when preparing coastal marine criteria The mean TP values for the nearshore reference sites at the northern terminus of the transect of stations is significantly higher than those at the southern end ($p = 0.0006$) even though the region is presumed to be geologically homogeneous.

- Secchi depth data were inconclusive because not enough data points were generated as a consequence of 24-hour sampling when Secchi depth could not be determined during night-time hours. Additional future sampling will be conducted during daylight so all parameters may be evaluated.

Committee Discussion of the Prototype Methodology

Fixed Station Sampling vs Stratified Random Sampling

Inferences derived from fixed-station and fixed-transect sampling, while common in oceanographic research and monitoring, are potentially confounded by unintentional and unknown biases, and by the inability to extend statistical inferences to the entire sample space desired. Alternatively, fixed stations tend to reduce the amount of unknown physical variability associated with interpreting climatic factors upon a given site such as when attempting to assess hurricanes, upwelling or acid deposition effects on a particular coastline. Although there is no reason to suspect that the existing stations of the mid-Atlantic coastal nutrient study are biased, the design group thought that the design should allow data inference to the entire coastal sampling space. It therefore proposes a change to a probability-based design, of equal sampling cost, to avoid the potential pitfalls of a fixed-station design.

The sample space for this project is open marine waters of the U.S. coastal zone, with emphasis on state waters within the 3 nautical mile state limit. Sampling will be carried out in three sampling strata for which nutrient conditions are to be estimated:

1. Reference areas within the 3-mile limit, outside the influence of major estuary plumes (e.g., Hudson River, Delaware Bay, Chesapeake Bay);

2. Nutrient influenced areas within the 3-mile limit, affected by the estuary plumes and other discharges; and

3. Offshore waters beyond the state 3-mile limit.

These three regions will define the sampling strata. The sampling design will be to define longshore "cells" in each of these three zones. During each sampling event, one site will be selected randomly within each sampling cell. The overall design can be described as stratified-systematic-random; where the strata are the three areas defined by estuary influence and distance from shore, the systematic component is the cells that define each stratum, and the random component is the random sampling location selected on each cell during each sampling event (Figure H-3).

The first task in developing the sampling plan will be to define areas of presumed estuarine influence, from existing physical oceanographic research on water movement, in this case in the mid-Atlantic coastal area, and from existing water chemistry data showing elevated nutrients and other constituents such as salinity and conductivity in the estuary plumes. Because plumes will vary with estuarine discharge, Gulf Stream eddies, and other events, precise definition of the plume area is not possible. Instead, plume areas should be defined as where the estuarine influence is likely to occur. An understanding of local estuarine hydrology will help in this regard, but extensive and expensive physical investigations should not be a prerequisite for the determination of likely plume influence.

Coastal reference site determinations and reference condition derivation should be, at least initially, established by EPA. Data collection would be continued as an EPA function because the offshore stations are the purview of the Federal government and because the related reference sites can be incorporated in the effort.

Estuarine and riverine plume monitoring are more likely accomplished by the coastal States using existing budgets and vessels already at their disposal. A coordinated effort relating State and Federal sampling and data exchange should be promoted. The nutrient quality of the discharge plumes can then be expeditiously compared to the proximal reference condition(s) to assess impact upon the near coastal marine waters.

Regional coastal characteristics will determine both the reference site cell structures and placement and the estuarine or riverine plume sampling designs.

Sampling Times and Depths

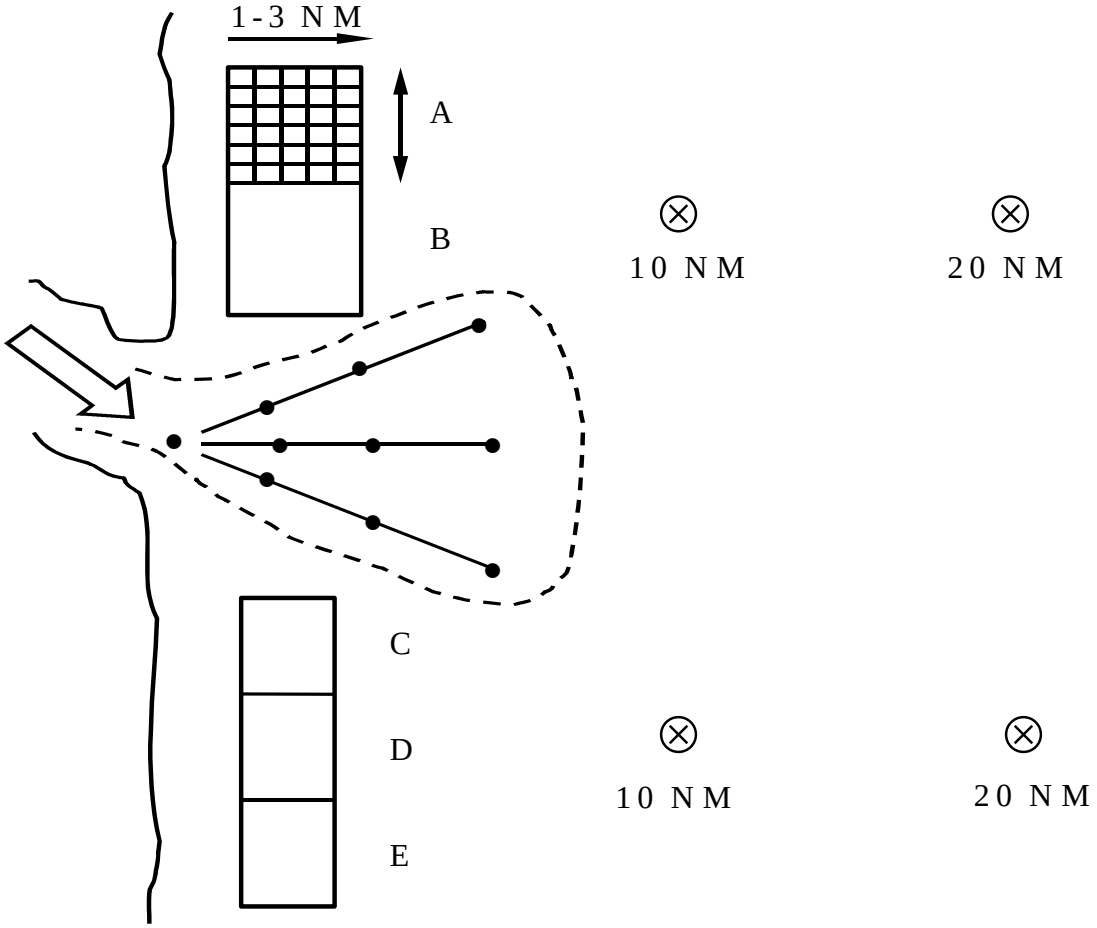
The committee recommended that sampling be conducted during the period of optimal marine vegetative growth. In temperate areas this is Spring and Summer, generally May, June and July, August. Other interval options depending on locale might be wet and dry periods during the growing season.

As a cost effective approach producing scientifically valid results, sampling depth is recommended as always at the surface, i.e., top meter of water accompanied by either a composite sample from the remainder of the water column or sampling from just below the thermocline and at one meter above the bottom. Some members of the committee advocate the surface, mid-depth, and bottom sampling technique where the mid-depth sample is usually below the thermocline and/or where inshore waters often fail to demonstrate a thermocline.

Variables

The primary four variables of TN, TP, Chlorophyll-*a*, and SD are recommended because they are the best early indicators of causal and biological response indicators to nutrient loadings. Other measures of clarity or transparency may also be used, but Secchi depth should always be included because such a large body of information is already available in this form; it is inexpensive and reliable; and continued Secchi depth measurements provide a continuity with much historical data. In an independent

Figure H-3. Illustration of stratified random grid sample design for reference condition cells as related to an estuarine discharge. Nutrient quality and spatial extent of the grid can be compared to a value derived from the measurements in reference sites (cells) A-E. Values at 10 and 20 nm stations are a check against reference values found at A-E.



investigation, the Swedish Environmental Protection Agency selected the same four primary variables (Report 5052, 2000).

Other recommended variables are: dissolved oxygen as an important secondary response variable almost always measured by investigators because of the significance of respiration to the biological community, and planktonic species composition as a refined diagnostic indicator of the nature and extent of enrichment.

Geographic Application of the Protocol

Members of the committee are familiar with both the East, West, and Gulf coasts of the continental U.S. and conclude that the method described above, with allowances for regional modifications such as relative distance from shore to shelf break and the magnitude of upwelling, can be successfully applied in all three coastal environments to identify reference conditions for criteria development.

Summary Conclusions

1. The basic protocol as described, but modified to include a probability-based sampling design, a variation on the surface, mid-depth, and bottom sampling profile, and sampling emphasis on twice during the growing season, is a scientifically defensible and broadly applicable method for establishing regional reference conditions to support coastal marine nutrient criteria development.

2. The TP, TN, Chlorophyll-*a*, and perhaps Secchi depth variables are responsive and together with salinity measurements are descriptive of both estuarine discharge plumes and near coastal reference quality waters. These measurements can be used to assess the concentration and area changes of discharge plumes over time.

3. The comparison of marine nutrient water quality to inshore reference sites is valuable as confirmation of "natural" reference conditions and as a graphic descriptor of the reference concept for the public. However, for cost effectiveness, these off shore stations need not be monitored every time the inshore reference sites are sampled.

4. But it is important to note that the distinction of cultural from inherent nutrient discharges by estuaries and other tributaries to coastal waters is not possible just by comparison to reference conditions. The other elements of nutrient criteria development should be incorporated to help make this distinction. The reference conditions and criteria will reveal exceedences of the "natural" background levels to be preferred and the relative extent and magnitude of the problem, but source identification and cause and effect studies will be required for an effective management response to this identified concern.